

State of California
The Resources Agency
Department of Water Resources
Environmental Services Office

FEATHER RIVER STUDY CHINOOK SALMON EMIGRATION SURVEY

December 1997 – June 1998

November 1999

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Summary

This report presents the results from the third season (December 1997 to June 1998) of the Feather River Study chinook salmon emigration survey. Rotary screw fish traps (RSTs) were the main sampling device for the emigration survey. This was the first season that the RSTs were fished for the entire season.

Two RSTs were used to collect data on the emigration of chinook salmon in the lower Feather River. One RST was deployed at approximately river mile (rm) 60, at the downstream end of the low flow channel (hereafter referred to as the Thermalito RST). A second was deployed downstream of Honcut Creek (the lower end of the study area) at approximately rm 42 (hereafter referred to as the Live Oak RST). In recent years the majority of salmon spawning has occurred in the low flow channel where flow is typically maintained at 600 cubic feet per second (cfs). Flows in the lower reach can range from 1,000 to 150,000 cfs with the majority of water entering the river through the Thermalito Afterbay Outlet.

Data were collected on chinook salmon and steelhead as well as other fish species. A total of 28 species was caught, the highest diversity since the study was initiated. Native species were prevalent, representing 10 of the 15 most abundant fish. Catch was dominated by 336,377 juvenile salmon captured between 27 December 1997 and 30 June 1998. Of the total salmon catch, 248,962 fish (74%) were captured in the Thermalito RST and 87,415 (26%) were captured in the Live Oak RST. Emigration estimates based on these data and trap efficiency results suggest that more salmon were produced in the low flow channel than in the lower reach. The majority of the juvenile salmon captured were parr (100% of the catch at the Thermalito RST and 99% of the catch at the Live Oak RST), demonstrating that most Feather River salmon emigrate well before smoltification. Salmon size ranged from 27 to 113 mm FL, but most (98%) were 50 mm or less. Salmon emigration was observed as soon as the traps were installed in December, peaked the last week of January, and continued through June.

A total of 155 young-of-the-year and ten juvenile steelhead of other age classes were captured between 4 January and 13 June 1998. The capture of both of these life stages suggests that Feather River supports at least modest in-channel production of steelhead.

Introduction

In 1991 the California Department of Water Resources (DWR), in cooperation with the California Department of Fish and Game (DFG), began the Feather River study to examine the effects of temporary water transfers between the State Water Project and Yuba County Water Agency on chinook salmon and other fish. The initial study sought to determine the effect of flow on fish habitat. Study objectives included the development of a flow model using Instream Flow Incremental Methodology (IFIM) and a temperature model.

In 1995, the study was expanded to gather fish data in support of the Federal Energy Regulatory Commission (FERC) relicensing of the State Water Project's Oroville Complex and to address issues raised by the Central Valley Project Improvement Act's (CVPIA) Anadromous Fish Restoration Program (USFWS 1997a). To this end, DWR initiated a number of studies on the lower Feather River consisting of five major elements: (1) chinook salmon spawning; (2) emigration; (3) chinook salmon spawning gravel evaluation; (4) hatchery tagging program; and (5) a Feather River literature database.

In 1997, DWR became a participant in the CVPIA's Comprehensive Assessment and Monitoring Program (CAMP) (USFWS 1997b) by contributing 1996 rotary screw trap (RST) data to the CAMP database. Additionally the study's activities were expanded to include water temperature monitoring throughout the lower river.

In 1998 the study was expanded to include estimation of survival of in-channel produced salmon (coded-wire tagging), beach seining survey, salmon egg survival and redd superimposition study, and additional water temperature monitoring. DWR continued to participate in the CAMP in 1998.

The salmon emigration survey is a major element of the Feather River study. This element examines the timing and magnitude of emigration of naturally produced salmon relative to different physical conditions and spawning population size. Although the element's main focus is salmon, data were also collected on steelhead, splittail, and other fish species.

Salmon emigration is monitored primarily using RSTs. Two RSTs are installed, one at the lower end of each of the two study reaches, and operated for approximately six months (mid-December through June). Two RSTs are necessary because flow is more strictly regulated in the low flow channel than in the reach below Thermalito, and therefore emigration cues and species composition may be different for the two reaches. In addition, supplemental sampling with beach seines is done to provide additional information about rearing and emigration behavior.

The emigration of salmonids and other species has not been monitored in the Feather River since the 1970s (Painter and others 1977). The US Fish and Wildlife Service and the DFG have recently increased their fish monitoring activities (using RSTs and other gear) in the Sacramento and San Joaquin River systems. This study will make a valuable contribution to the increasing pool of knowledge about fish populations in the Central Valley and provide information about fish movement in the Feather River. Other fish monitoring on the lower Feather River consists of a chinook salmon spawning survey (carcass counts) and an angler survey conducted by the DFG.

The salmon emigration element objectives aim to achieve the following:

1. Document general salmonid emigration attributes, such as timing, abundance and composition (by species, race, and life stage).
2. Investigate the influence of factors thought to initiate emigration, such as flow, turbidity, and water temperature.
3. Develop annual juvenile salmon production indices by relating information on spawning intensity to emigration data. The indices will be used to examine the effects of different physical and biological factors on Feather River salmon production.

Methods

Study Area

The lower Feather River (Figure 1) is located within the Central Valley of California, draining an extensive area of the western slope of the Sierra Nevada. The reach between Oroville Dam and the confluence with the Sacramento River is of low gradient. Above Lake Oroville, the river has three forks, the North, Middle, and South Forks, which meet at the lake. Lake Oroville, created by the completion of Oroville Dam in 1967, has a capacity of approximately 3.5 million acre-feet (maf) of water and is a multi-use reservoir providing flood control, water supply, power generation, and recreation. Flow in the lower Feather River below the reservoir is regulated through releases from Oroville Dam, Thermalito Diversion Dam, and the Thermalito Afterbay Outlet. Under normal operations, the majority of water released from Lake Oroville is diverted at Thermalito Diversion Dam into the Power Canal and Thermalito Forebay. The remainder of the flow, typically 600 cubic feet per second (cfs), flows through the historical river channel, typically referred to as the “low flow channel.” Water released from the Forebay is used to generate power as it is discharged into Thermalito Afterbay. Water is returned to the Feather River through Thermalito Afterbay Outlet, then flows southward through the lower reach to the confluence with the Sacramento River at Verona. The Feather River study area (Figure 2) is 23 river miles long and consists of the low flow channel, which extends from the Fish Barrier Dam at river mile (rm) 67.25 to Thermalito Outlet (rm 59), and a lower reach which extends from Thermalito Outlet to Honcut Creek (rm 44). The confluence with the Yuba River (RM 27.5) is 16.5 river miles further downstream from Honcut Creek. The study is focused on the upper 23 river miles (rm 44 to 67) of the lower river because it is the portion of the river where salmonid spawning occurs. River miles 0 to 44 are comprised mostly of flatwater habitat with substrates consisting mostly of fines.

The Fish Barrier Dam, just downstream of the Thermalito Diversion Dam, is the upper limit for upstream migrating fish. The base of the Fish Barrier Dam is where the fish ladder begins, guiding fish into Feather River Hatchery. The hatchery was built by DWR to mitigate for loss of chinook salmon and steelhead spawning and rearing habitat resulting from construction of Oroville Dam.

Data Collection

Two eight-foot RSTs are the main sampling devices used for the emigration survey. RSTs are sturdy, relatively easy to move within the stream, relatively easy to operate and maintain, are able to capture fish without harm in fast-moving water, and can be used to sample continuously. An RST operates in the following manner to capture fish: with the trapping cone lowered into flowing water, water strikes the baffles on the inside of the trapping cone, causing the cone to rotate. Fish enter the upstream end of the rotating trapping cone, become trapped inside the trapping cone, and are carried rearward into a livebox. One RST was placed at the downstream end of the low flow channel at approximately rm 60, just upstream of the Thermalito Outlet (see Figure 2). The other was placed in the lower reach near the town of Live Oak (approximately rm 42) (see Figure 2). Separate RSTs are needed because operation of the Oroville Complex results in two substantially different flow regimes: flow in the low flow channel is more strictly regulated and is generally relatively low and constant (600 cfs); the lower reach (below Thermalito Outlet), is subject to flow fluctuations and flows can range from 1,700 to 40,000+ cfs during emigration. Therefore, emigration cues and species composition may be different for the two reaches. The RST sites were selected based on the following criteria for RST installation, operation, and maintenance: (1) suitable depth (greater than six feet at minimum flow); (2) suitable velocity (greater than two feet per second at minimum flow); (3) suitable anchoring point(s); and (4) relatively limited public access.

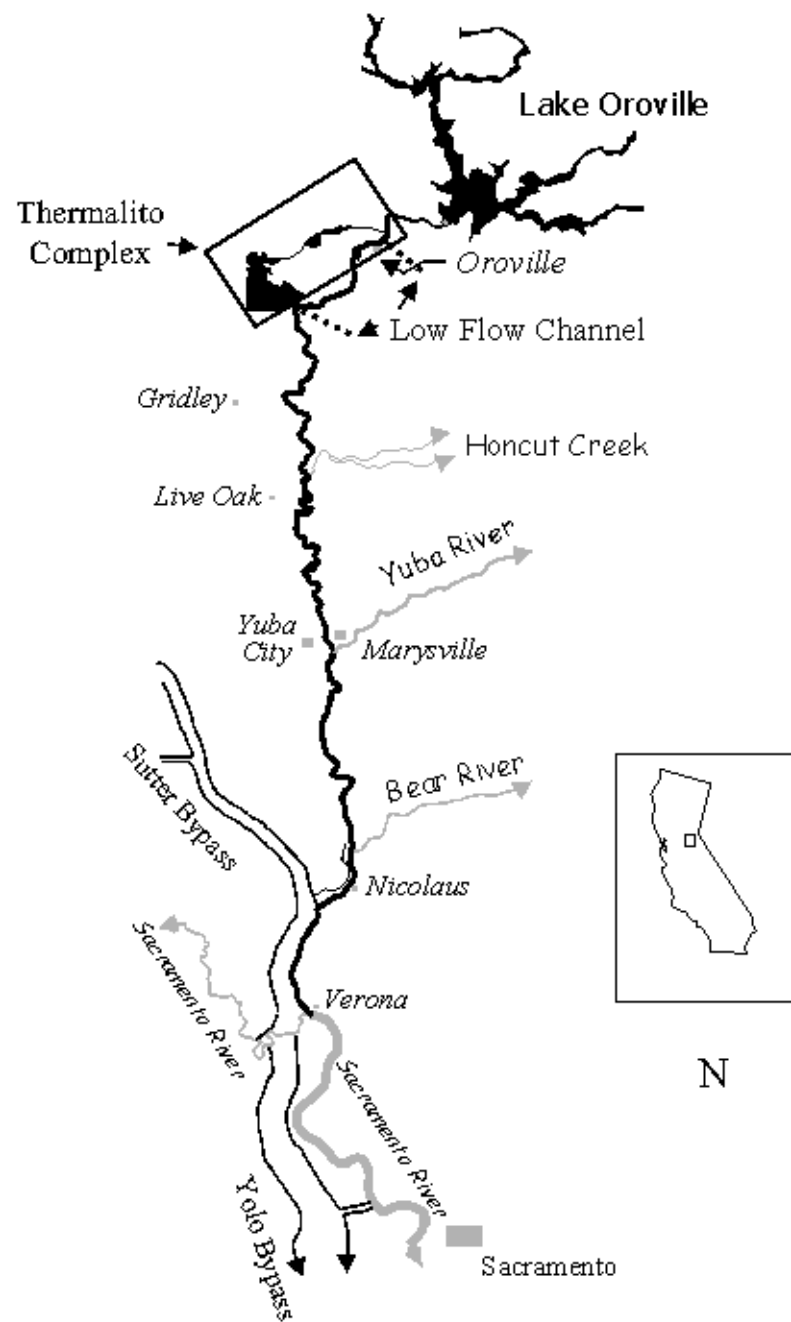


Figure 1 Lower Feather River and associated tributaries between Oroville Dam and the confluence with the Sacramento River

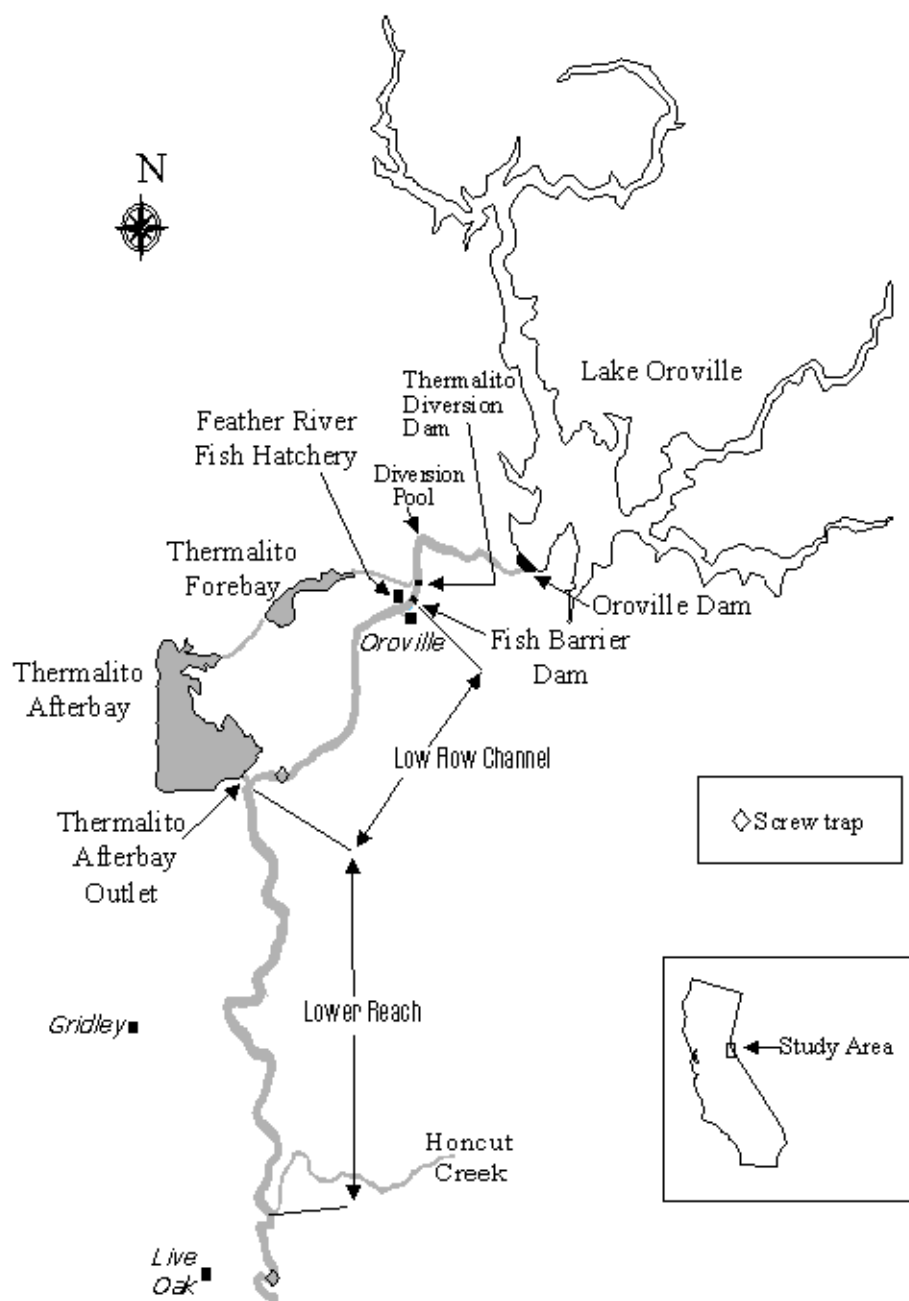


Figure 2 Feather River study area

The RSTs were fished continuously for approximately 6.5 months (mid-December through June), except for short periods when river conditions became unsafe. Both RSTs were serviced at least once a day in the morning and more often when there was a high load of debris. During servicing, trapped fish were removed from the livebox, identified to species and counted. Fork length (to the nearest millimeter) was measured for up to 50 individuals of each species. The fish were then released back to the river, except for salmon retained for coded-wire tagging.

Chinook salmon individuals that were measured were also inspected for characters such as presence of parr marks, silvery appearance, and deciduous scales to determine life stage and degree of smolting. A simple life stage designation was determined for each salmon measured:

- P clearly parr = a darkly pigmented fish with characteristic dark, oval- to round-shaped parr marks on its sides
- X intermediate = the fish is not clearly parr, but is not yet clearly a smolt either; it is something between parr and smolt
- S clearly a smolt = highly faded or completely lacking parr marks, bright silver or nearly white color, and deciduous scales

The percentages of each life stage in the daily subsamples were used to calculate the number of each life stage captured each week at each RST. The values resulting from the calculations are referred to as “expanded numbers.”

A salmon tagging station was set up at the Thermalito Afterbay Outlet to coded-wire tag (CWT) in-channel produced juvenile salmon. Juvenile salmon captured in the RSTs were transported to the tagging station where they were tagged by a contractor, Big Eagle and Associates. Five lots of CWT half-tags (Northwest Marine Technology, Inc., Washington) were used. The tagged salmon were held overnight, a subsample was checked for tag shedding, and then the tagged salmon were released just downstream of the Live Oak boat ramp unless they were used for RST efficiency evaluations.

Other data were also collected daily at each RST: water clarity (secchi depth), water temperature, the length of time the RST fished during the sample period (number of hours fished since last service), average trapping cone revolutions per minute, and the total number of trapping cone revolutions during the sampling period. These parameters were selected to increase consistency of this project with other fish monitoring projects conducted in the Sacramento River system. Flow data came from DWR records of releases from Oroville Dam and Thermalito Afterbay Outlet.

RST efficiency was evaluated using fish collected in the RSTs. Three evaluations were conducted using the CWT in-channel produced salmon. Marked fish were released approximately one kilometer upstream of each RST, and RST catch was monitored for recaptures over the four days after marked fish were released. The average Thermalito RST efficiency value was used to calculate an estimate of the number of fish emigrating from the low flow channel. The average Live Oak RST efficiency value was used to calculate an estimate of the number of fish emigrating from the river. Total catch was estimated by summing the daily catch for the season. The emigration estimates are calculated by dividing the total salmon catch in a RST by the average RST efficiency value for that RST:

$$\text{Emigration Estimate} = \text{Total catch in RST} \div \text{Average RST efficiency value}$$

The emigration estimate for the river could then be used to calculate an “emigration index” value for the river using the DFG spawning escapement estimate for the previous fall. The emigration index is a spawning, escapement-corrected, production estimate value that may be used to compare annual production from year to year. The index is calculated by dividing the emigration estimate for the river by the estimated spawning escapement value from the previous fall divided by two. The estimated spawning escapement was divided by two, based on the assumption that the spawning population consisted of an even number of males and females.

$$\text{Emigration Index} = \text{Emigration Estimate} \div [\text{DFG spawning escapement estimate} \div 2]$$

Results

Sampling Period

The RSTs were deployed from 22 December 1997 through 30 June 1998. There were two periods (one for eleven days (4 to 14 February 1998) and a second for seven days (26 March through 1 April 1998)) when trapping was stopped at both RSTs due to high flow conditions (peak flow events of 10,000 cfs in the low flow channel and about 25,000 cfs in the lower reach). From 12 through 15 January 1998, the Live Oak RST was only fished for several hours a day due to extremely high debris loads resulting from increased flows, and then not fished on 16 and 17 January 1998 in anticipation of further increases in debris load due to further flow increases. Other than these few short periods the RSTs were fished continuously for the 6.5 months they were deployed.

Flows

During the emigration survey, low flow channel flows were 900 cfs from 22 December 1997 through 2 March 1998, after which flows were reduced to the typical 600 cfs level from 3 March through 30 June 1998, except for two peak flow events (10,000 cfs) in February and March (Figure 3). The 900 cfs level was higher than normal for the period as part of water supply-related operation changes. Lower reach flows generally were in the 5,000 to 10,000 cfs range for most of the trapping period, but on three occasions exceeded 10,000 cfs (see Figure 3).

Water Quality

Water temperature ranged from 44 to 62 °F at the Thermalito RST and 46 to 65.5 °F at the Live Oak RST (see Figure 3). Water temperatures showed no apparent trend during winter, but generally increased during spring. Water temperature appeared to be inversely related to most of the major flow fluctuations. For example, water temperatures at the Live Oak RST were inversely related ($r = -0.83$) to flow fluctuations in the lower reach that occurred from early April through early May (see Figure 3).

Secchi depth was variable through the survey, but was generally lower during winter and higher in the spring (Figure 4). In general water clarity was greater in the low flow channel than in the lower reach (see Figure 4). It is typical for low flow channel water clarity to remain high because flows are usually constant and low. Lower reach water clarity can be influenced by flow fluctuations, the sediment load in the after-bay, and discharges from agricultural land adjacent to the river. During the last month of trapping, secchi depth at the Thermalito RST was in excess of three meters, while at the Live Oak RST it rarely exceeded two meters.

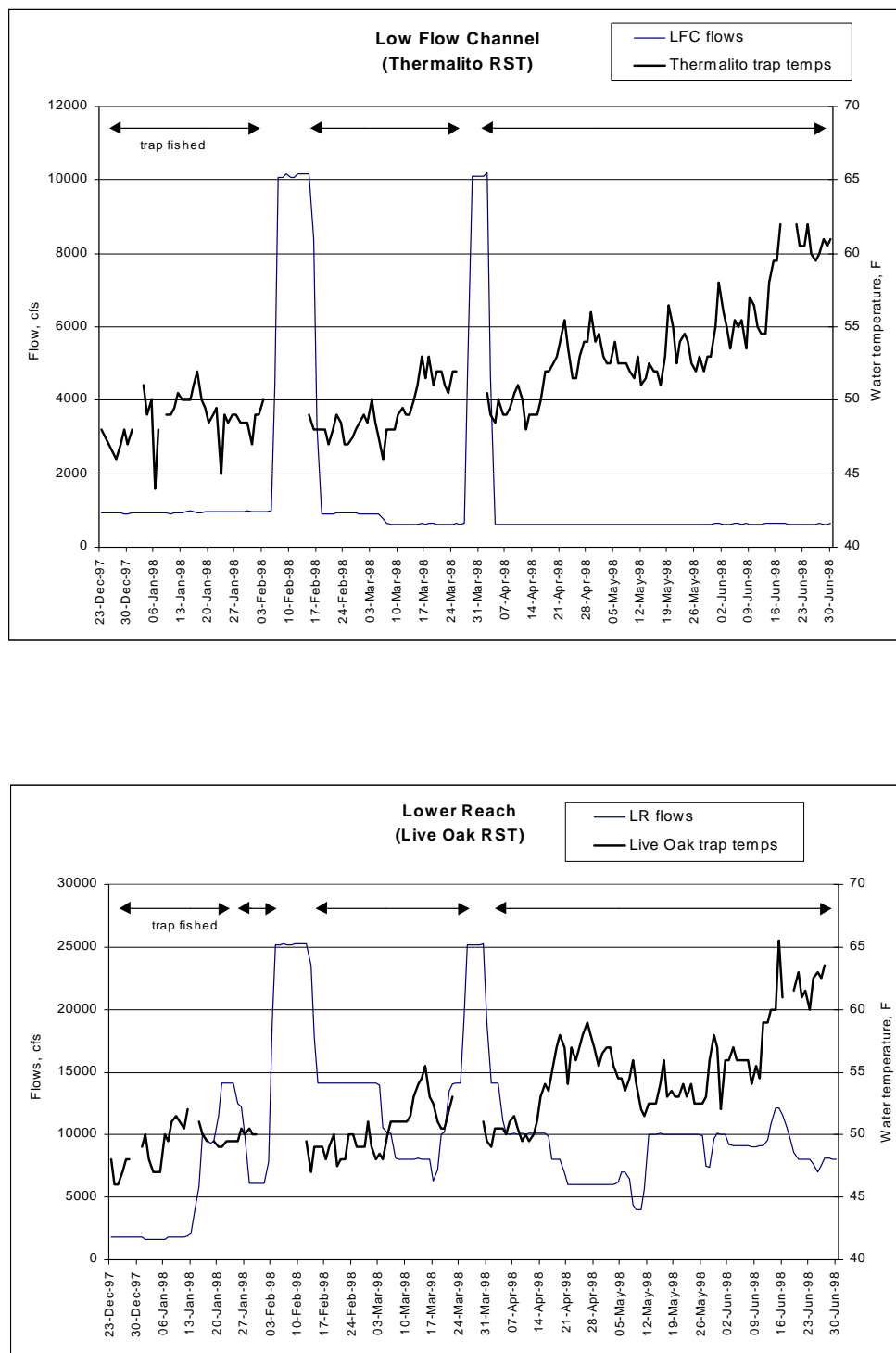


Figure 3 Water temperatures and flows during the lower Feather River chinook salmon emigration survey from December 1997 through June 1998

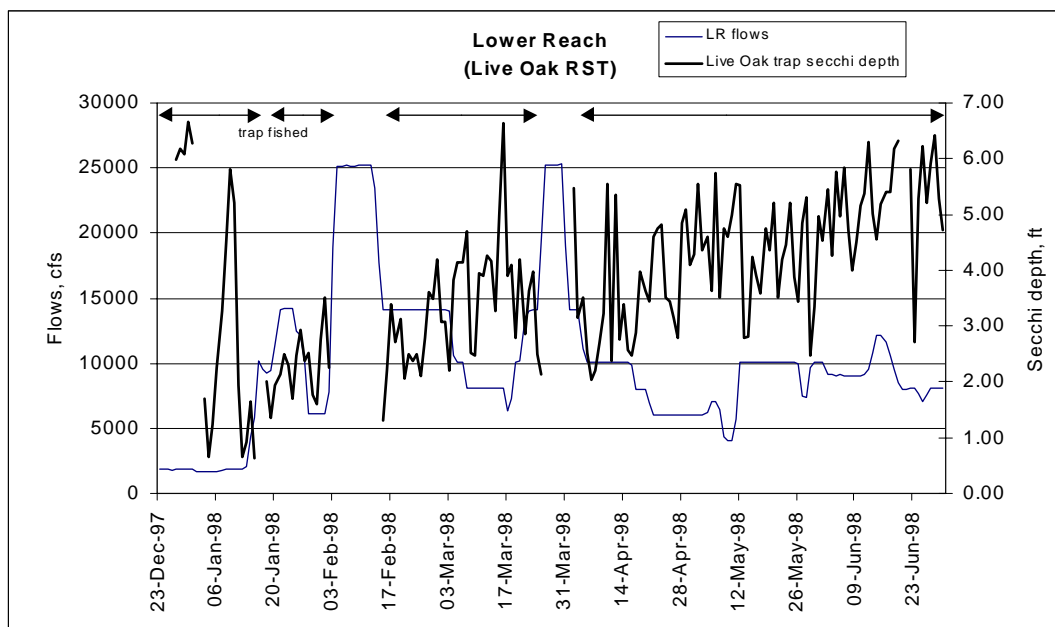
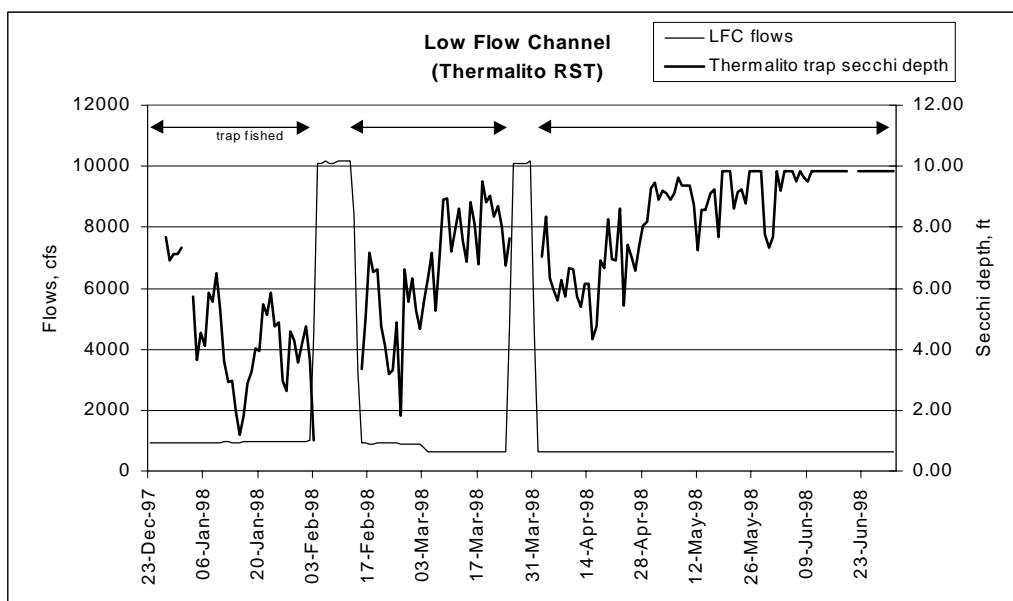


Figure 4 Water clarity and flows during the lower Feather River chinook salmon emigration survey from December 1997 through June 1998

RST Catch and Species Composition

Twenty-eight species were caught during the 1998 emigration survey (Table 1). This is the greatest number of species caught in three seasons of trapping (see Table 1). Twelve native and 16 introduced species were caught. The ten species or species groups captured in highest abundance were as follows (in order of prevalence): chinook salmon (*Onchorhynchus tshawytscha*), unidentified juveniles, bluegill (*Lepomis macrochirus*), juvenile lamprey (ammocetes, most likely Pacific lamprey, *Lampetra tridentata*), prickly sculpin (*Cottus asper*), Sacramento sucker (*Catostomus occidentalis*), golden shiner (*Notemigonus crysoleucas*), Pacific lamprey (adults), juvenile cyprinids, and wakasagi (*Hypomesus nipponensis*) (Table 2). Three species, American shad (*Alosa sapidissima*); black bullhead (*Ameiurus melas*); and striped bass (*Morone saxatilis*), were caught in the 1996 or 1997 emigration surveys but were not caught in the 1998 survey (see Table 1). Four species were caught in 1998 that were not captured in the 1996 or 1997 surveys: black crappie (*Pomoxis nigromaculatus*), bigscale logperch (*Percina macrolepida*), adult redeye bass (*Micropterus coosae*), and white crappie (*Pomoxis annularis*) (see Table 1). Total catch (both RSTs combined) was dominated by chinook salmon (98% of total catch). Thermalito RST total catch was 99% salmon and Live Oak RST total catch was 96% salmon.

Salmon Emigration

Chinook salmon emigration was detected throughout all 27 weeks of trapping (22 December 1997 through 30 June 1998) (Figure 5, Table 3). A season total of 336,377 salmon was caught in 7,764 hours of fishing effort (43.3 fish/h). Peak catch occurred in January and declined for the duration of sampling.

Salmon were caught in both RSTs as soon as they were deployed. Salmon catch at each RST was as follows: Thermalito RST, 248,962 fish in 3,971 hours of fishing effort (62.7 fish/h); Live Oak RST, 87,415 fish in 3,793 hours of fishing effort (23.0 fish/h). The highest daily catch at Thermalito was 22,521 on 15 January 1998 (Figure 6); the highest daily catch at Live Oak was 6,774 on 21 January 1998 (Figure 7). At the peak of emigration in January, there were two peaks in salmon catch at each RST. At Thermalito, the two peaks occurred 13 days apart on 15 January 1998 (22,521 salmon with average fork length of 34.4 mm) and 28 January 1998 (17,505 salmon with average fork length of 34.8 mm). At Live Oak the two peaks occurred nine days apart on 21 January 1998 (6,774 salmon with average fork length of 34.8 mm) and 30 January 1998 (6,313 salmon with average fork length of 34.8 mm). The highest weekly catches (see Figure 5) were as follows: Thermalito, 72,573 during week 3 (11 to 17 January 1998); Live Oak, 20,616 during week 4 (18 to 24 January 1998). While salmon catch declined steadily at Thermalito starting in February (see Figure 6), it declined from mid-February through mid-March then continued somewhat steadily until mid-May at Live Oak (see Figure 7). The Thermalito RST continued to catch a few salmon up to the last day of trapping (30 June 1998). No salmon were caught in the Live Oak RST after 18 June.

Salmon size ranged from 27 to 113 mm FL (Figure 8, see Table 3). Mean weekly length ranged from 34.2 to 100.7 mm (see Table 3). Mean weekly length range was typically similar between RSTs (see Table 3). Mean fork length at each RST remained about the same (about 35 to 36 mm) until approximately mid-March then increased steadily through the end of trapping (Figures 9 and 10). Approximately 97% of the Thermalito catch ($n = 4,216$) and 72% of the Live Oak catch ($n = 5,364$) was comprised of fish less than 50 mm FL (Figures 11 and 12, respectively). Overall, approximately 83% of the total salmon catch was less than 50 mm FL.

Table 1 Summary of fish species caught during the lower Feather River chinook salmon emigration survey from December 1997 through June 1998

Species or Group	Origin	1997	1998						Total
		Dec	Jan	Feb	Mar	Apr	May	Jun	
black crappie	Introduced		11				1	1	13
bluegill sunfish	Introduced	2	524	25	12	119	57	18	757
brown bullhead	Introduced						1		1
carp	Introduced					2	3	4	9
chinook salmon	Native	1595	227965	79687	23994	2355	724	57	336377
golden shiner	Introduced	7	10	2			53	317	389
green sunfish	Introduced		3	2				1	6
hardhead	Native							1	1
hitch	Native						1	113	114
largemouth bass	Introduced		17	3		2	84	34	140
logperch	Introduced		1						1
mosquito fish	Introduced		2	2		2	4		10
Pacific lamprey	Native	9	145	7	8	13	8	4	194
prickly sculpin	Native	14	315	38	29	59	17	22	494
redeer sunfish	Introduced		29		1				30
redeye bass	Introduced						1		1
rifle sculpin	Native		4	6	4	6	3	2	25
river lamprey	Native					2	1	2	5
Sacramento splittail	Native						20	34	54
Sacramento squawfish	Native		15	24	10	5	7	3	64
Sacramento sucker	Native		1			110	55	225	391
smallmouth bass	Introduced					1	6	11	18
steelhead (juveniles of other age classes)	Native		5	1	1	2			9
steelhead (young-of-the-year)	Native	1			29	110	15	1	156
threadfin shad	Introduced		3	1			1		5
tule perch	Native	1		1	3	3	1	1	10
wakasagi	Introduced	24	73	25	13	7	12	6	160
warmouth	Introduced		27	3		6	6	4	46
white crappie	Introduced	1	10					1	12
juvenile bass (<i>Micropterus</i> sp.) ^a	Introduced						1	19	20
juvenile centrarchid (non- <i>Micropterus</i> sp.) ^a	Introduced		19		2				21
juvenile cyprinid ^a	Mixed					9	4	158	171
juvenile lamprey (ammocete) ^a	Native	5	340	72	81	52	82	67	700
juvenile sculpin ^a	Native		3			1	6	58	68
unidentified juvenile ^b	Mixed					15	577	2240	2832
Total									343304

^a Individuals not identified to species (usually identified to genus or family).^b Small (<45mm, often larval-sized) fish that could not be identified in the field.

Table 2 Summary of RST catch during the first three seasons of the lower Feather River chinook salmon emigration survey

<i>Species or Group</i>	<i>Origin</i>	<i>1995-1996 04 Mar to 30 Jun</i>	<i>1996-1997 02 Oct to 27 Dec</i>	<i>1997-1998 22 Dec to 30 Jun</i>
American shad	Introduced	✓		
black bullhead	Introduced		✓	
black crappie	Introduced			✓
bluegill	Introduced	✓	✓	✓
brown bullhead	Introduced	✓		✓
carp	Introduced	✓		✓
chinook salmon	Native	✓	✓	✓
golden shiner	Introduced	✓		✓
green sunfish	Introduced		✓	✓
hardhead	Native	✓		✓
hitch	Native	✓		✓
largemouth bass	Introduced	✓	✓	✓
logperch	Introduced			✓
mosquitofish	Introduced	✓	✓	✓
Pacific lamprey	Native	✓	✓	✓
prickly sculpin	Native	✓	✓	✓
red eye bass	Introduced			✓
redeer sunfish	Introduced	✓	✓	✓
rifle sculpin	Native		✓	✓
river lamprey	Native	✓		✓
Sacramento splittail	Native	✓		✓
Sacramento squawfish	Native	✓	✓	✓
Sacramento sucker	Native	✓	✓	✓
smallmouth bass	Introduced	✓		✓
steelhead (young-of-the-year)	Native	✓		✓
steelhead (juveniles of other age classes)	Native	✓		✓
striped bass	Introduced	✓		
threadfin shad	Introduced	✓	✓	✓
tule perch	Native	✓		✓
wakasagi	Introduced	✓	✓	✓
warmouth	Introduced	✓	✓	✓
white crappie	Introduced			✓
juvenile bass (<i>Micropterus</i> sp.)	Introduced	✓		✓
juvenile centrarchid (non- <i>Micropterus</i> sp.)	Introduced	✓	✓	✓
juvenile cyprinid	Mixed	✓	✓	✓
juvenile lamprey (ammocete)	Native	✓	✓	✓
juvenile sculpin	Native			
unidentified juvenile	Mixed	✓	✓	✓
Total Number of Species		24	15	28

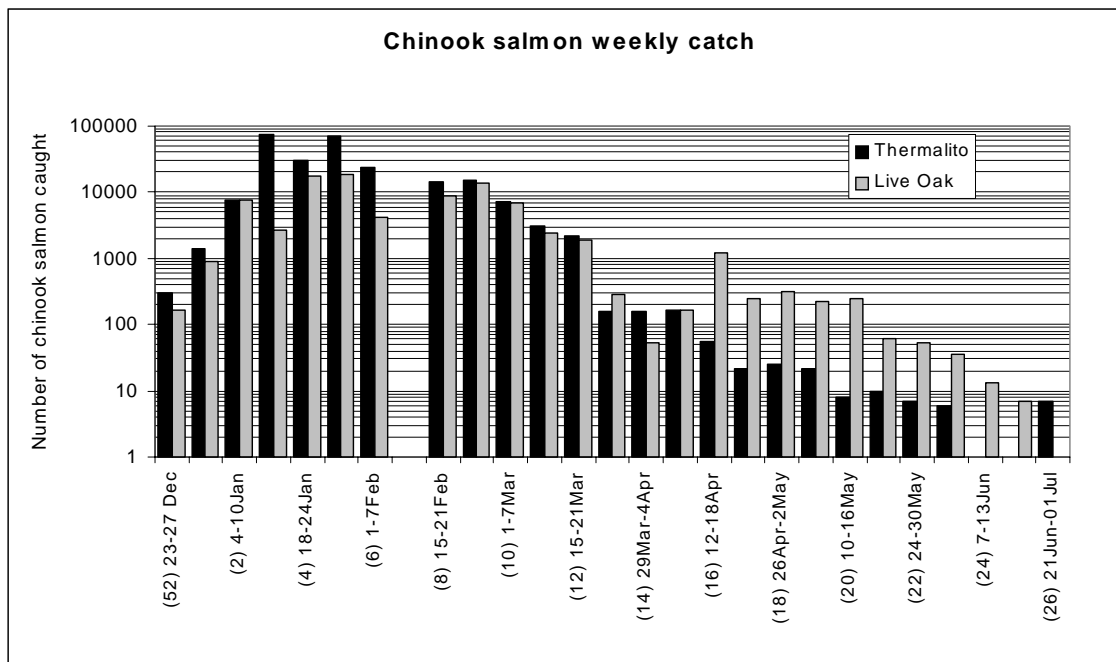


Figure 5 Weekly catch of chinook salmon caught by RSTs during the lower Feather River chinook salmon emigration survey from December 1997 through June 1998. () = week number. RSTs not fished from 4 to 17 February and 26 March through 1 April 1998.

Parr comprised the entire salmon catch in the Thermalito RST and approximately 99% of the salmon catch at Live Oak (Table 4). Both RSTs caught very few smolts, but the Live Oak RST caught more than the Thermalito RST. The Thermalito RST caught fewer “intermediate” fish than the Live Oak RST (see Table 4).

Three efficiency evaluations were conducted for each RST. Recapture rate in the Thermalito RST ranged from 0.0175 to 0.0039 and in the Live Oak RST from 0 to 0.0053. Average RST efficiencies were 0.8% at Thermalito and 0.2% at Live Oak.

Based on total catch and mean trap efficiency, the 1998 emigration estimates were as follows:

- low flow channel: 31,120,250 juvenile salmon
- river: 43,707,500 juvenile salmon

The 1998 emigration index was not calculated because the 1997 spawner estimate was unavailable from DFG.

Table 3 Summary of chinook salmon catch statistics for the lower Feather River chinook salmon emigration survey from December 1997 through June 1998

		Size Statistics (FL) in mm			
Week and Dates	Total Catch	Mean	Minimum	Maximum	Standard Deviation
Thermalito RST					
(52) 23 - 27 Dec	306	33.9	29	38	1.59
(1) 28 Dec - 03 Jan	1373	34.3	29	39	1.55
(2) 04 - 10 Jan	7399	35.0	30	39	1.63
(3) 11 - 17 Jan	72573	35.1	27	40	1.77
(4) 18 - 24 Jan	30639	35.5	30	40	1.57
(5) 25 - 31 Jan	70362	35.6	32	39	1.46
(6) 01 - 07 Feb	23288	36.1	31	39	1.37
(7) 08 - 14 Feb	(no data - trap not fished this week)				
(8) 15 - 21 Feb	14447	36.0	32	43	1.65
(9) 22 - 28 Feb	15490	36.0	32	42	1.57
(10) 01 - 07 Mar	7114	36.1	31	41	1.43
(11) 08 - 14 Mar	3138	36.2	32	41	1.47
(12) 15 - 21 Mar	2194	36.0	31	45	1.69
(13) 22 - 28 Mar	156	36.7	31	63	3.52
(14) 29 Mar - 04 Apr	154	41.7	31	74	8.36
(15) 05 - 11 Apr	164	41.1	34	69	6.40
(16) 12 - 18 Apr	56	42.6	34	79	9.10
(17) 19 - 25 Apr	22	54.0	33	85	15.54
(18) 26 Apr - 02 May	25	61.2	36	90	12.32
(19) 03 - 09 May	22	69.9	53	85	9.06
(20) 10 - 16 May	8	73.8	66	78	4.33
(21) 17 - 23 May	10	78.4	34	91	16.56
(22) 24 - 30 May	7	85.6	75	94	8.26
(23) 31 May - 06 Jun	6	79.8	40	107	22.09
(24) 07 - 13 Jun	1	91.0	91	91	
(25) 14 - 20 Jun	1	91.0	91	91	
(26) 21 Jun - 01 Jul	7	100.7	93	109	6.50
Total or Average	248962	52.8	43	65	5.87
Overall Min or Max			27	109	

Table 3 (Continued) Summary of chinook salmon catch statistics for the lower Feather River chinook salmon emigration survey from December 1997 through June 1998

Week and Dates	Total Catch	Size Statistics (FL) in mm			Standard Deviation
		Mean	Minimum	Maximum	
Live Oak RST					
(52) 23 - 27 Dec	162	34.5	30	38	1.57
(1) 28 Dec - 03 Jan	911	34.6	28	38	1.69
(2) 04 - 10 Jan	7707	35.7	28	43	1.84
(3) 11 - 17 Jan	2688	36.2	29	43	2.11
(4) 18 - 24 Jan	17278	35.7	31	46	1.80
(5) 25 - 31 Jan	18162	36.1	29	43	2.09
(6) 01 - 07 Feb	4094	35.8	30	41	1.73
(7) 08 - 14 Feb		(no data - trap not fished this week)			
(8) 15 - 21 Feb	8922	36.6	32	47	2.12
(9) 22 - 28 Feb	13446	36.9	32	66	3.14
(10) 01 - 07 Mar	6814	36.4	30	53	2.20
(11) 08 - 14 Mar	2417	36.7	33	45	1.83
(12) 15 - 21 Mar	1872	38.0	32	72	4.72
(13) 22 - 28 Mar	289	40.6	33	76	8.66
(14) 29 Mar - 04 Apr	54	48.1	34	81	11.07
(15) 05 - 11 Apr	164	52.2	29	85	10.23
(16) 12 - 18 Apr	1230	53.7	33	87	7.87
(17) 19 - 25 Apr	241	58.2	35	87	8.80
(18) 26 Apr - 02 May	323	63.6	45	95	8.48
(19) 03 - 09 May	224	68.8	53	100	7.60
(20) 10 - 16 May	248	72.4	48	113	8.38
(21) 17 - 23 May	62	74.2	63	90	6.65
(22) 24 - 30 May	52	80.4	64	96	7.33
(23) 31 May - 06 Jun	35	83.4	74	101	6.44
(24) 07 - 13 Jun	13	87.8	68	101	8.63
(25) 14 - 20 Jun	7	89.3	82	98	4.82
(26) 21 Jun - 01 Jul		(0 salmon caught at Live Oak this week)			
Total or Average	87415	52.2	41	71.4	5.27
Overall Min or Max			28	113	

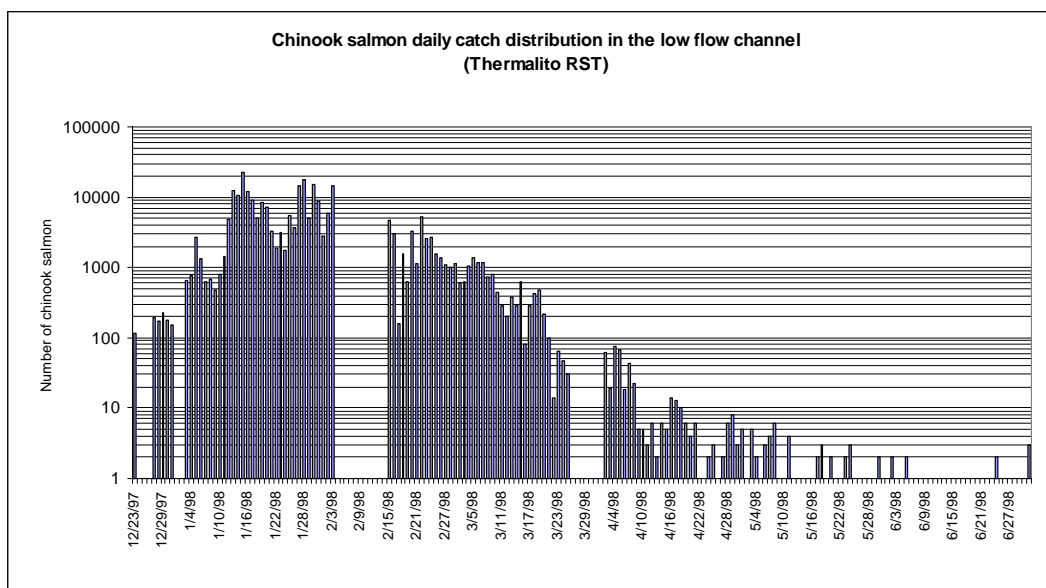


Figure 6 Daily catch distribution of chinook salmon caught by RST during the lower Feather River chinook salmon emigration survey from December 1997 through June 1998. The Thermalito RST was not fished from 4 to 14 February and 26 March through 1 April 1998.

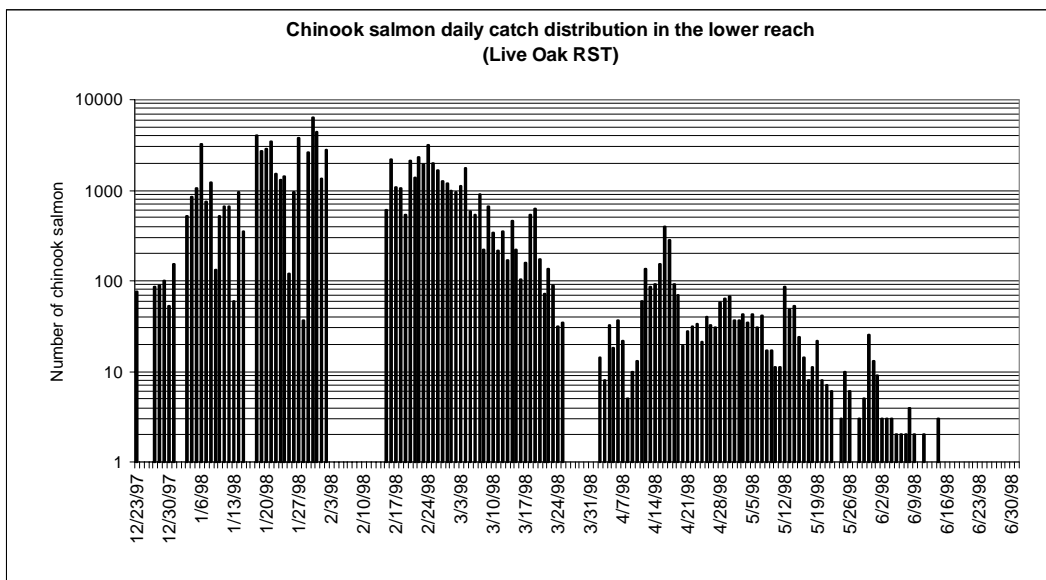


Figure 7 Daily catch distribution of chinook salmon caught by RST during the lower Feather River chinook salmon emigration survey from December 1997 through June 1998. The Live Oak RST was not fished on 16 and 17 January, 4 to 14 February, and 26 March through 1 April 1998.

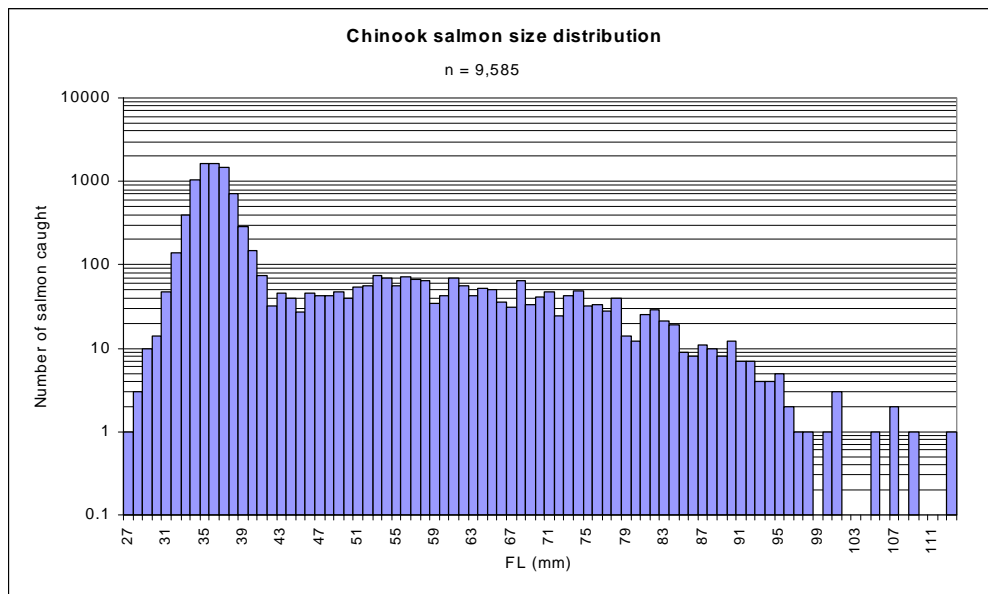


Figure 8 Length-frequency distribution of chinook salmon caught by RSTs during the lower Feather River chinook salmon emigration survey from December 1997 through June 1998

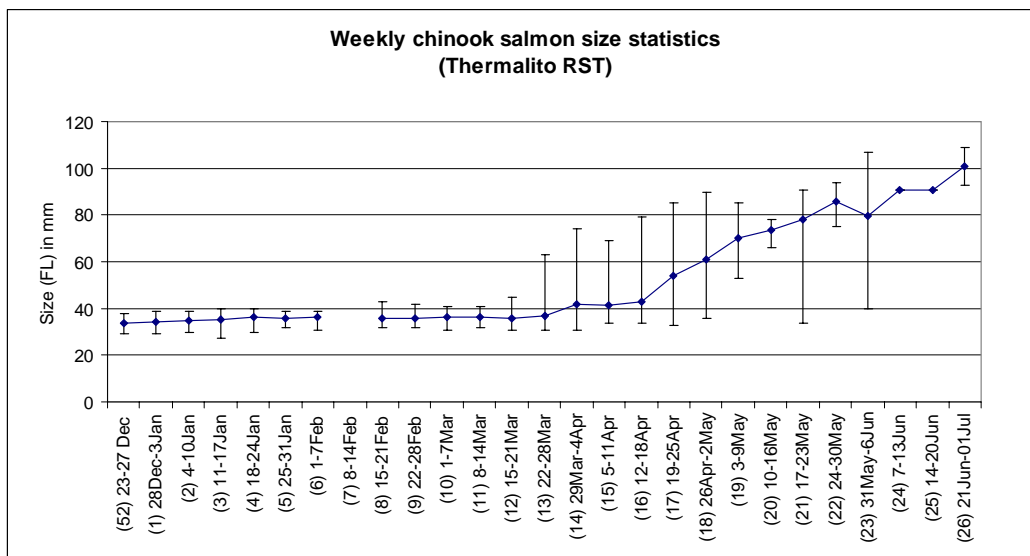


Figure 9 Mean length and size range of chinook salmon caught by RST during the lower Feather River chinook salmon emigration survey from December 1997 through June 1998. () = week number. The Thermalito RST was not fished from 4 to 14 February and 26 March through 1 April 1998.

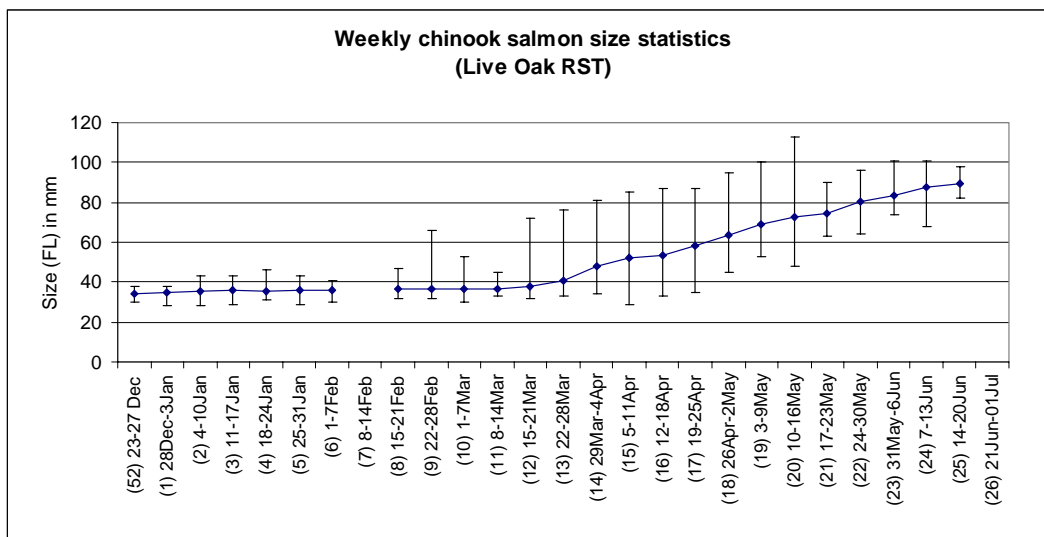


Figure 10 Mean length and size range of chinook salmon caught by RST during the lower Feather River chinook salmon emigration survey from December 1997 through June 1998. () = week number. The Live Oak RST was not fished from 4 to 17 February and 26 March through 1 April 1998.

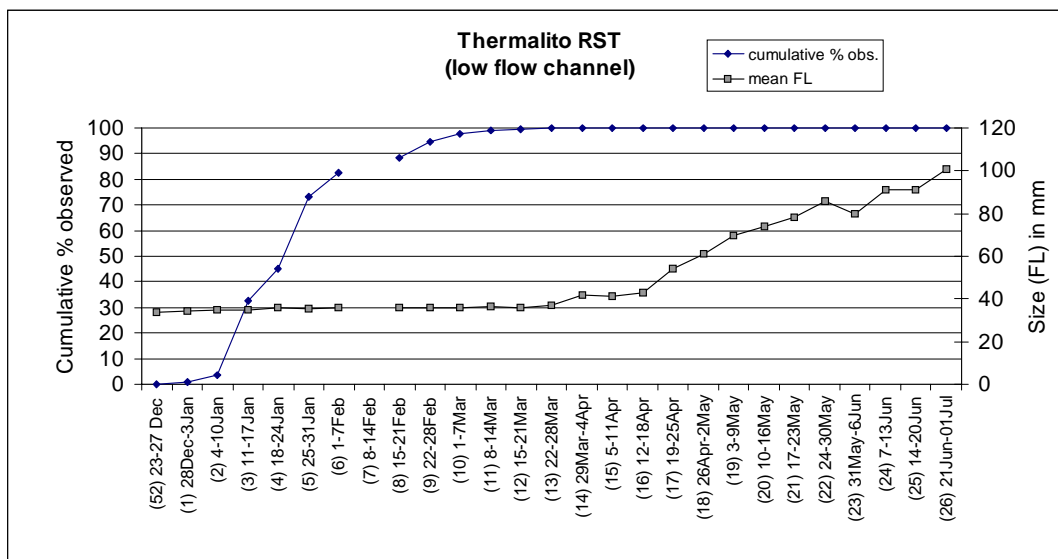


Figure 11 Cumulative catch and weekly average size during the lower Feather River chinook salmon emigration survey from December 1997 through June 1998. () = week number. The Thermalito RST was not fished from 4 to 14 February and 26 March through 1 April 1998.

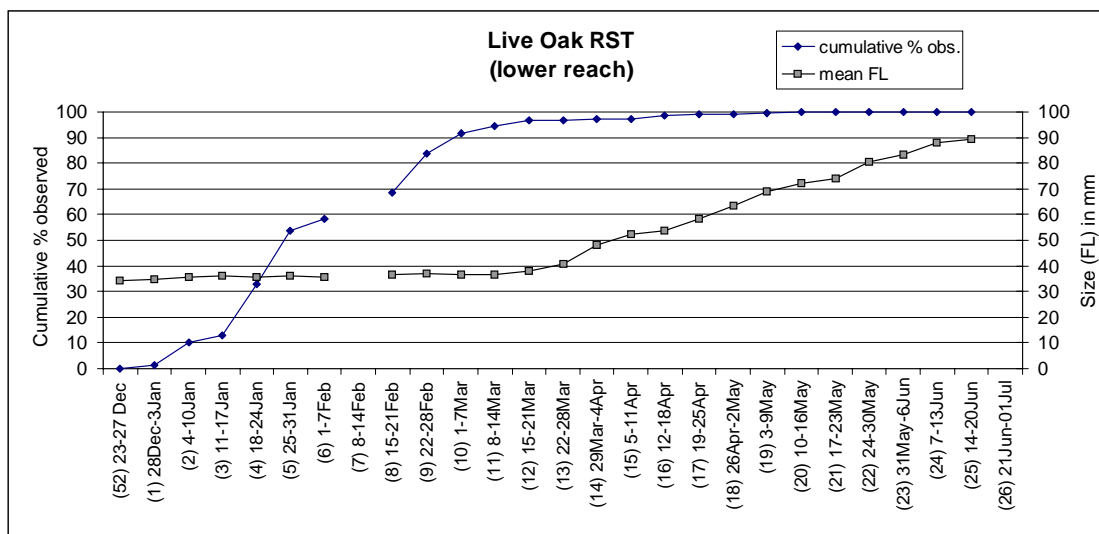


Figure 12 Cumulative catch and weekly average size of chinook salmon during the lower Feather River chinook salmon emigration survey from December 1997 through June 1998. () = week number. The Live Oak RST not fished from 4 to 17 February and 26 March through 1 April 1998.

Coded-wire Tagging of In-channel Produced Salmon

A total of 63,989 in-channel produced juvenile salmon was coded-wire tagged and released over a two month period (25 January 1998 through 22 March 1998). CWT fish were typically released at the Live Oak boat ramp unless they were used for RST efficiency evaluations. Nine of these fish were recovered in US Fish and Wildlife Service sampling (trawl) at Chipps Island in the Sacramento-San Joaquin Delta. Six of the fish were from two groups released between 26 January and 2 February 1998 and between 21 and 28 February 1998, and were recovered in the Delta between 20 April and 15 June 1998. Three of the fish were in the group released between 7 and 23 March 1998 and were recovered in the Delta between 22 May and 12 June 1998.

Steelhead

Steelhead (*Onchorhynchus mykiss*) captured incidentally in the RSTs consisted of young-of-the-year (YOY) fish (typically <100 mm FL) and juvenile fish of other age classes (typically 100 to 300 mm FL). No adults were captured. YOY fish were caught from weeks 11 (8 to 14 March 1998) through 24 (7 to 13 June 1998) (Figure 13). A total of 155 YOY fish were caught. YOY size ranged from 22 to 47 mm FL (mean = 27.1 mm) (Figure 14; Table 5).

The larger juveniles of other age classes were caught between weeks 2 (4 to 10 January 1998) and 11 (8 to 14 March 1998) (see Figure 13) and ranged in size from 183 to 243 mm FL (mean = 215.6 mm) (see Figure 14, see Table 5). A total of ten juveniles of other age classes were captured including four that were hatchery fish (ad-clipped). The marked fish were recorded as such, and then released.

Table 4 Expanded catch distribution of chinook salmon life stages caught by RSTs during the lower Feather River chinook salmon emigration survey from December 1997 through June 1998

Week	<i>Thermalito</i>			<i>Live Oak</i>		
	<i>Parr</i>	<i>Intermediate</i>	<i>Smolt</i>	<i>Parr</i>	<i>Intermediate</i>	<i>Smolt</i>
(52) 23 - 27 Dec	306	0	0	162	0	0
(1) 28 Dec - 03 Jan	1373	0	0	911	0	0
(2) 04 - 10 Jan	7399	0	0	7707	0	0
(3) 11 - 17 Jan	72573	0	0	2688	0	0
(4) 18 - 24 Jan	30639	0	0	17278	0	0
(5) 25 - 31 Jan	70362	0	0	18162	0	0
(6) 01 - 07 Feb	23288	0	0	4094	0	0
(7) 08 - 14 Feb	(trap was not fished this week)			(trap was not fished this week)		
(8) 15 - 21 Feb	14447	0	0	8922	0	0
(9) 22 - 28 Feb	15490	0	0	13446	0	0
(10) 01 - 07 Mar	7114	0	0	6814	0	0
(11) 08 - 14 Mar	3138	0	0	2417	0	0
(12) 15 - 21 Mar	2194	0	0	1872	0	0
(13) 22 - 28 Mar	156	0	0	289	0	0
(14) 29 Mar - 04 Apr	154	0	0	54	0	0
(15) 05 - 11 Apr	164	0	0	159	5	0
(16) 12 - 18 Apr	56	0	0	1157	73	0
(17) 19 - 25 Apr	17	5	0	194	47	0
(18) 26 Apr - 02 May	14	11	0	152	167	3
(19) 03 - 09 May	6	16	0	32	190	2
(20) 10 - 16 May	1	7	0	6	241	1
(21) 17 - 23 May	1	9	0	0	62	0
(22) 24 - 30 May	0	7	0	0	51	1
(23) 31 May - 06 Jun	0	5	1	0	32	3
(24) 07 - 13 Jun	0	1	0	0	9	4
(25) 14 - 20 Jun	0	1	0	0	2	5
(26) 21 Jun - 01 Jul	0	6	1	0	0	0
Total	248892	68	2	86517	878	20
Mean Proportion (%)	100	0	0	99	1	0

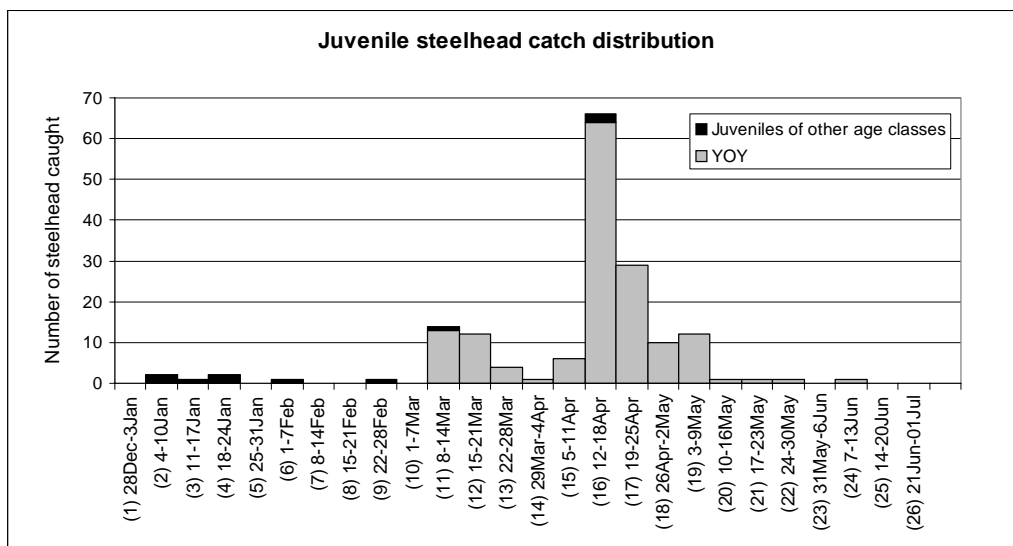


Figure 13 Catch and distribution of juvenile steelhead caught by RSTs during the lower Feather River chinook salmon emigration survey from December 1997 through June 1998. () = week number. RSTs were not fished from 4 to 17 February and 26 March through 1 April 1998.

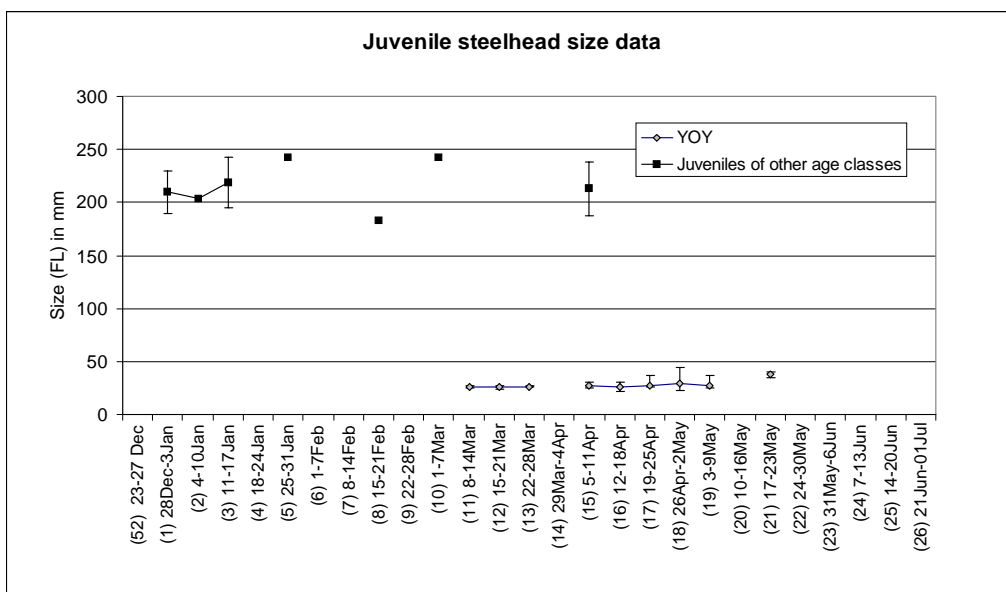


Figure 14 Mean fork length and size range of juvenile steelhead caught by RSTs during the lower Feather River emigration survey from December 1997 through June 1998. () = week number. RSTs were not fished from 4 to 17 February 1998 26 March through 1 April 1998.

Table 5 Summary of steelhead catch statistics for the lower Feather River chinook salmon emigration survey from December 1997 through June 1998 ^a

Week and Dates	Thermalito RST (low flow channel)				Live Oak RST (lower reach)			
	Young-of-the-year		Juveniles of Other Age Classes		Young-of-the-year		Juveniles of Other Age Classes	
	Count	Mean FL (mm) and Range	Count	Mean FL (mm) and Range	Count	Mean FL (mm) and Range	Count	Mean FL (mm) and Range
(52) 23 - 27 Dec								
(1) 28 Dec - 03 Jan							2	210 (190 - 230)
(2) 04 - 10 Jan							1	204
(3) 11 - 17 Jan			2	219 (195 - 243)				
(4) 18 - 24 Jan								
(5) 25 - 31 Jan			1	243				
(6) 01 - 07 Feb								
(7) 08 - 14 Feb								
(8) 15 - 21 Feb			1	183				
(9) 22 - 28 Feb								
(10) 01 - 07 Mar							1	243
(11) 08 - 14 Mar	13	26 (25 - 27)						
(12) 15 - 21 Mar	12	26 (24 - 27)						
(13) 22 - 28 Mar	4	27 (26 - 27)						
(14) 29 Mar - 04 Apr	1	26						
(15) 05 - 11 Apr	6	27 (25 - 30)	1	187			1	238
(16) 12 - 18 Apr	64	26 (22 - 30)						
(17) 19 - 25 Apr	28	28 (26 - 27)			1	26		
(18) 26 Apr - 02 May	10	30 (23 - 44)						
(19) 03 - 09 May	12	27 (25 - 37)						
(20) 10 - 16 May	1	26						
(21) 17 - 23 May	2	38 (35 - 40)						
(22) 24 - 30 May								
(23) 31 May - 06 Jun								
(24) 07 - 13 Jun					1	47		
(25) 14 - 20 Jun								
(26) 21 Jun - 01 Jul								
Total	153	37 (22 - 40)	5	208 (183 - 243)	2	(26 - 47)	5	224 (190 - 243)

^a Numbers in bold type indicate coded-wire tagged fish.

Discussion

RST Performance

The RSTs were moored in slightly different locations in 1998 than they were in 1996 and 1997 because of changes in the river resulting from the 1997 flood event. The Thermalito RST and Live Oak RST were moored approximately 100 feet and 438 feet, respectively, upstream of their 1996/97 locations. The Live Oak RST fished much better than it had in previous seasons because it was in a location in which velocity remained at suitable levels (3 feet per second) at all flow levels. Water velocity was periodically marginal at the 1996 site. Conversely, the Thermalito RST did not fish as well in 1998 as it did in 1996 and 1997. Larger releases from the Thermalito Afterbay Outlet resulted in a backwater effect at the downstream end of the low flow channel, which caused sub-optimal water velocities. Despite the backwater effect, the Thermalito RST had higher trap efficiencies (0.89%) than the Live Oak site (0.2%) as a result of the relatively narrow stream width at the Thermalito RST location and almost constant flows in the low flow channel. The higher 1998 RST efficiencies at Thermalito were consistent with the 1996 results (DWR 1999a). Using CWT in-channel produced salmon worked well in the 1998 RST efficiency evaluations. The tagging operation provided a constant, plentiful, and convenient supply of marked fish.

RST Catch and Species Composition

The 1998 survey confirmed previous findings: the Thermalito RST catches more fish than the Live Oak RST. Thermalito caught 73% and Live Oak caught 27% of the season total catch compared to the 1996 survey results when Thermalito caught 61% and Live Oak caught 39% of the total catch (DWR 1999a).

The large numbers of salmon resulted in a high proportion of native fish in the catch. Review of the catch numbers including salmon resulted in proportions of 100% native species at Thermalito and 98% native to 2% introduced species at Live Oak. Native fish were also prevalent in terms of relative abundance. Of the 15 most abundant species captured, ten were native (chinook salmon, juvenile lamprey, prickly sculpin, Sacramento sucker, Pacific lamprey, steelhead, hitch (*Lavinia exilicauda*), juvenile sculpin (*Cottus* sp.), Sacramento squawfish (*Ptychocheilus grandis*), and splittail (*Pogonichthys macrolepidotus*).

Species composition in the 1998 emigration survey was similar to sampling in 1967 through 1975, when 35 species were captured (Painter and others 1977). The notable difference in species composition between the 1996-1998 surveys and the results of Painter and others (1977) is the variety of sportfish: coho salmon (*Onchorhynchus kisutch*), chum salmon (*O. keta*), pink salmon (*O. gorbuscha*), sockeye salmon (*O. nerka*), brown trout (*Salmo trutta*), channel catfish (*Ictalurus punctata*), and white sturgeon (*Acipenser transmontanus*). Painter and others (1977) reported that the salmon species other than chinook were probably not common in the Feather River and did not represent reproducing populations.

Wakasagi continued in high abundance in the 1998 survey although their numbers were less than in 1996. Species of introduced fish that were found in the 1998 emigration survey that were not caught in the 1996 or 1997 survey were black crappie, white crappie, bigscale logperch, and adult redeye bass. Although Painter and others (1977) did not find white crappie in their surveys, white crappie are probably not a recent immigrant. There is some evidence that they may have been planted in the Feather as early as 1891 (Dill and Cordone 1997), but it is more likely that they spread downstream after being introduced into Lake Oroville in 1978. Bigscale logperch were introduced into California at various times and locations

and continue to spread, however it is not clear how or when they reached the Feather River. They were collected from the Feather River near Oroville in 1974 (Dill and Cordone 1997). It is likely that black crappie and redeye bass dispersed downstream after being introduced into Lake Oroville.

Salmon Emigration

The 1998 Feather River emigration period was similar to 1996 (DWR 1999a) and the 1970s (Painter and others 1977). Salmon were caught as soon as the RSTs were deployed, indicating that emigration had begun before RST deployment. Fall 1996 RST data (DWR 1999b) showed that emigration began as early as mid-November. Painter and others (1977) found that the end of the emigration period on the Feather River varied, but could occur at least through the end of June. By contrast Warner (1955) found that emigration ended around 1 June (in 1955), a month earlier than the more recent surveys done by DFG (1968 through 1975) and DWR (1996 to present). Construction of Oroville Dam in 1967 has resulted in cooler temperatures in the low flow channel, perhaps slowing juvenile growth rates and extending the emigration period.

The 1998 peak was consistent with the late January through late February salmon emigration peak found in 1994-1996 lower American River emigration surveys (Snider and others 1998) and historical data for the Feather River (Painter and others 1977).

Chinook salmon size ranges in the 1998 emigration survey (27 to 113 mm FL) were comparable to those in the 1996 (March through June) Feather River emigration survey (25 to 121 mm FL). Salmon catch from the 1996 and 1998 surveys are difficult to compare directly since the 1996 (March through June) survey was conducted for a shorter period than in 1998. However, sampling occurred in both years during the March through June period when 27,130 salmon were caught in 1998 and 17,078 were caught in 1996.

Comparison of the 1998 and 1996 proportions of salmon, smaller and larger than 50 mm, found that the proportions were similar for Live Oak but slightly different for Thermalito. In the 1996 (March through June) survey the proportions of fish smaller than 50 mm were 81% at Thermalito and 71% at Live Oak compared to 97% at Thermalito and 72% at Live Oak in 1998. The difference in Thermalito values between 1996 (81%) and 1998 (97%) could be because the peak of emigration was probably missed in 1996.

The March through June 1996 survey results (DWR 1999a) suggested that most of the emigrating salmon were pre-smolt, and the 1998 survey data revealed the same pattern. In the 1998 emigration survey only a minute fraction of the juvenile salmon were smolts. Essentially all of the emigrating Feather River juvenile salmon were pre-smolt. The percentage of salmon that were clearly smolt or intermediate between parr and smolt was less than 0.3%. A high percentage of salmon was smaller than 50 mm FL (97% at Thermalito and 72% at Live Oak). The high percentages of pre-smolt fish and fish smaller than 50 mm indicate that salmon are not smolting in the upper half of lower Feather River and are likely undergoing smoltification in the river downstream of Live Oak or in the Sacramento-San Joaquin Estuary or San Francisco Bay.

Recapture dates of in-channel produced, CWT juvenile salmon released in late January through late February 1998 and also in late March 1998 indicate that the juveniles took six to eight weeks to travel from the upper half of the lower Feather River to Chipps Island at the downstream end of the Delta. At the time they were recaptured, the fish were smolts, 74 to 90 mm FL in size. The average size of these fish when they were released was 37 mm FL.

The 1998 coded-wire tagging was successful, and coded-wire tagging of in-channel produced juvenile salmon will be conducted again during the 1999 emigration survey. Eight tag codes will be used (compared to five codes used in the 1998 survey).

Effects of Flow, Water Clarity, and Water Temperature on Emigration

Emigration did not show a relationship with flow in the low flow channel ($r = 0.3$; $P < 0.05$), because releases to this reach are typically constant. However because the Thermalito RST was not fished during the flood control releases in February and March, there are no data to determine whether the increased flow during this period influenced emigration. This issue should be revisited after emigration data are collected during flow fluctuations in the low flow channel. There was a weak positive relationship between emigration and flows in the lower reach ($r = 0.6$; $P < 0.05$), indicating that higher flows may have increased emigration rates. The 1996 emigration survey found that emigration was not related to flow in either reach.

There appeared to be a weak negative relationship between water clarity and emigration. The regression coefficients for the number of salmon emigrants and water clarity at the Thermalito and Live Oak RSTs were -0.7 and -0.5 , respectively ($P < 0.05$). There was no apparent relationship between secchi depth and flows ($r_{\text{Thermalito}} = -0.4$; $r_{\text{Live Oak}} = -0.2$; $P < 0.05$) or secchi depth and precipitation ($r_{\text{Thermalito}} = -0.4$; $r_{\text{Live Oak}} = -0.3$; $P < 0.05$) in either reach of the river. This suggests that local surface runoff may be more important to water clarity than dam releases.

The 1998 evaluation of emigration and water clarity differed from 1996 results which found that there was no correlation between water clarity and emigration in either reach of the river. Like 1996, emigration was not clearly related to with water temperature ($r_{\text{Thermalito}} = 0.3$; $r_{\text{Live Oak}} = -0.4$; $P < 0.05$).

Emigration Estimates and Index

The relatively high emigration estimate for the low flow channel (31,120,250 salmon) compared to the river (43,707,500 salmon) is consistent with the finding that the majority of salmon are presently spawning in the low flow channel (Sommer and others forthcoming).

The 1998 survey is the first time a full-season emigration estimate could be generated. When spawner estimates are available from DFG, an emigration index will be calculated and compared to future Feather River surveys.

Steelhead

Although not many steelhead were caught, the presence of YOY and juveniles of other age classes indicates that there is at least modest natural production in the Feather River. Yearlings were caught during the January through April period, suggesting an extended emigration period consistent with other valley rivers (DWR and USBR 1999). The lower catch numbers of juvenile steelhead is probably attributable to their low abundance in the Feather River and also because steelhead emigrate at a larger size, mostly as two- and three-year-old fish (Hallock and others 1961). The larger emigrating steelhead are able to avoid the RSTs much more readily than the smaller emigrating salmon. The numbers of steelhead caught in the 1998 survey were slightly different from the numbers caught in the 1996 survey: 155 YOY and 10 juveniles of other age classes in 1998 compared to 83 YOY and 15 juveniles of other age classes in 1996. The greater number of YOY caught in 1998 suggests in-river production of steelhead may have been greater in 1998 than in 1996. Assuming that hatchery yearling steelhead were released at the usual locations at Gridley (rm 50), Live Oak (rm 42), Yuba City (rm 28), and Boyd Pump (rm 23), it is interesting to note that the fish

moved upstream at least as far as the Thermalito RST (rm 60) as indicated by the capture of three hatchery (ad-clipped) steelhead in the Thermalito RST.

Acknowledgments

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